

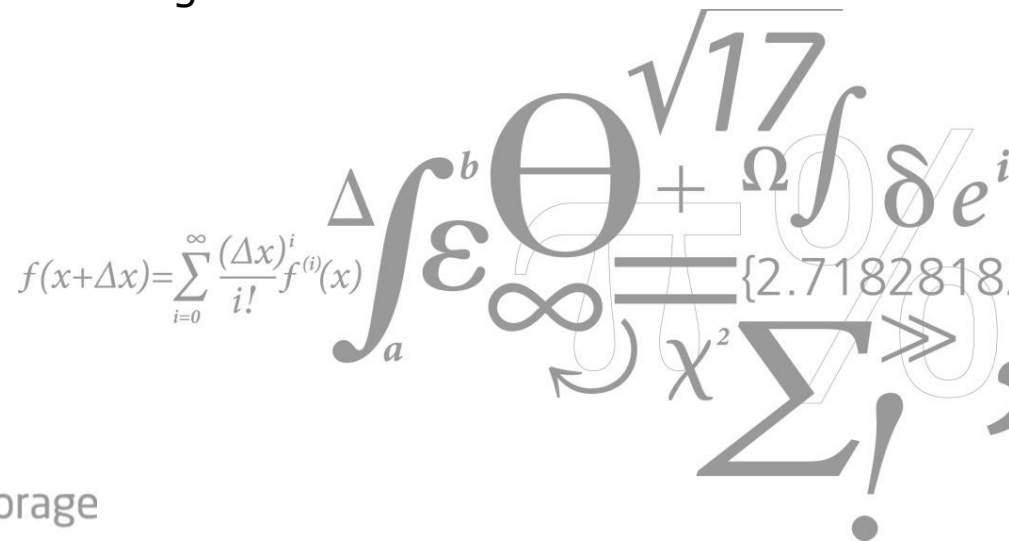
Feeding CO₂ from air into solid oxide electrolyzer cells

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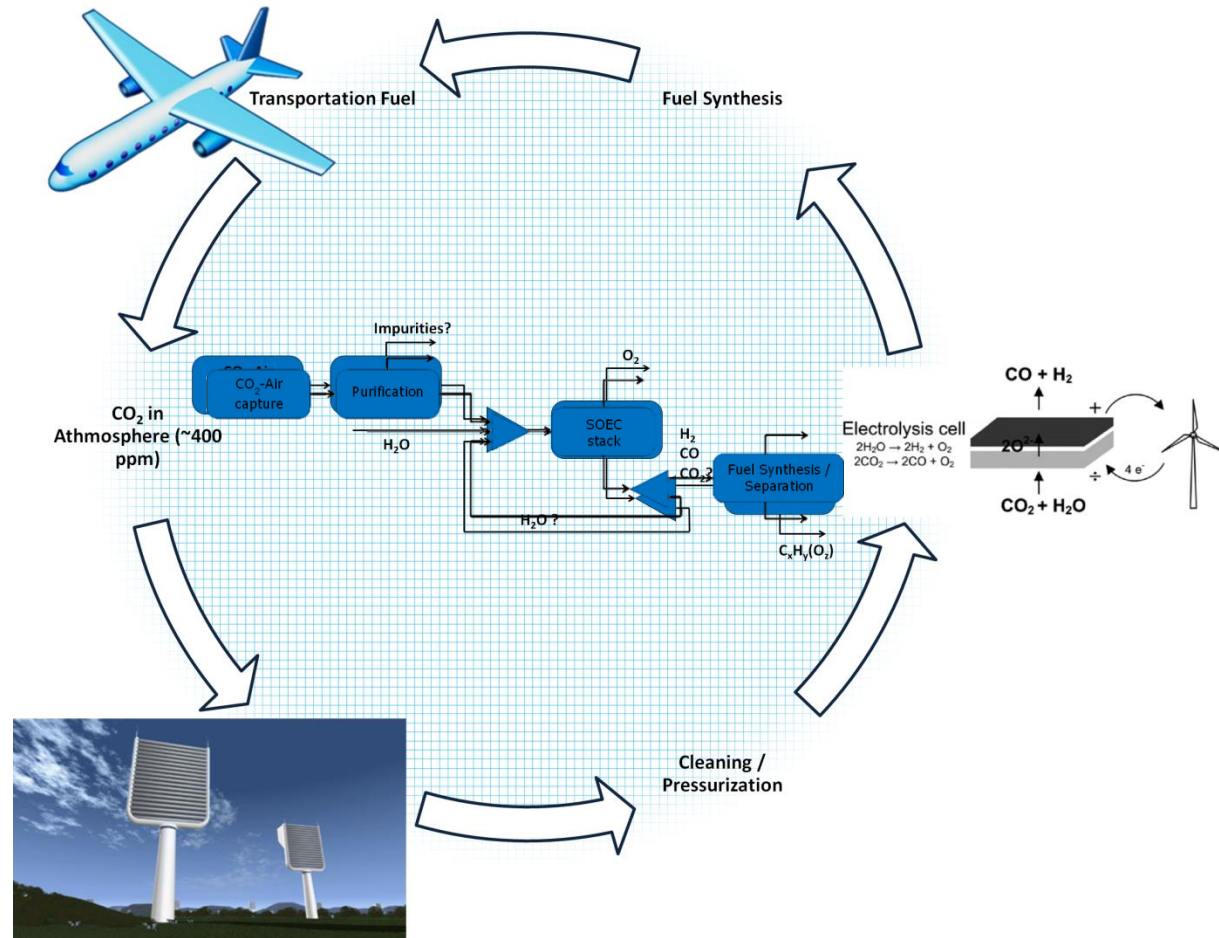
Department of Energy Conversion and Storage
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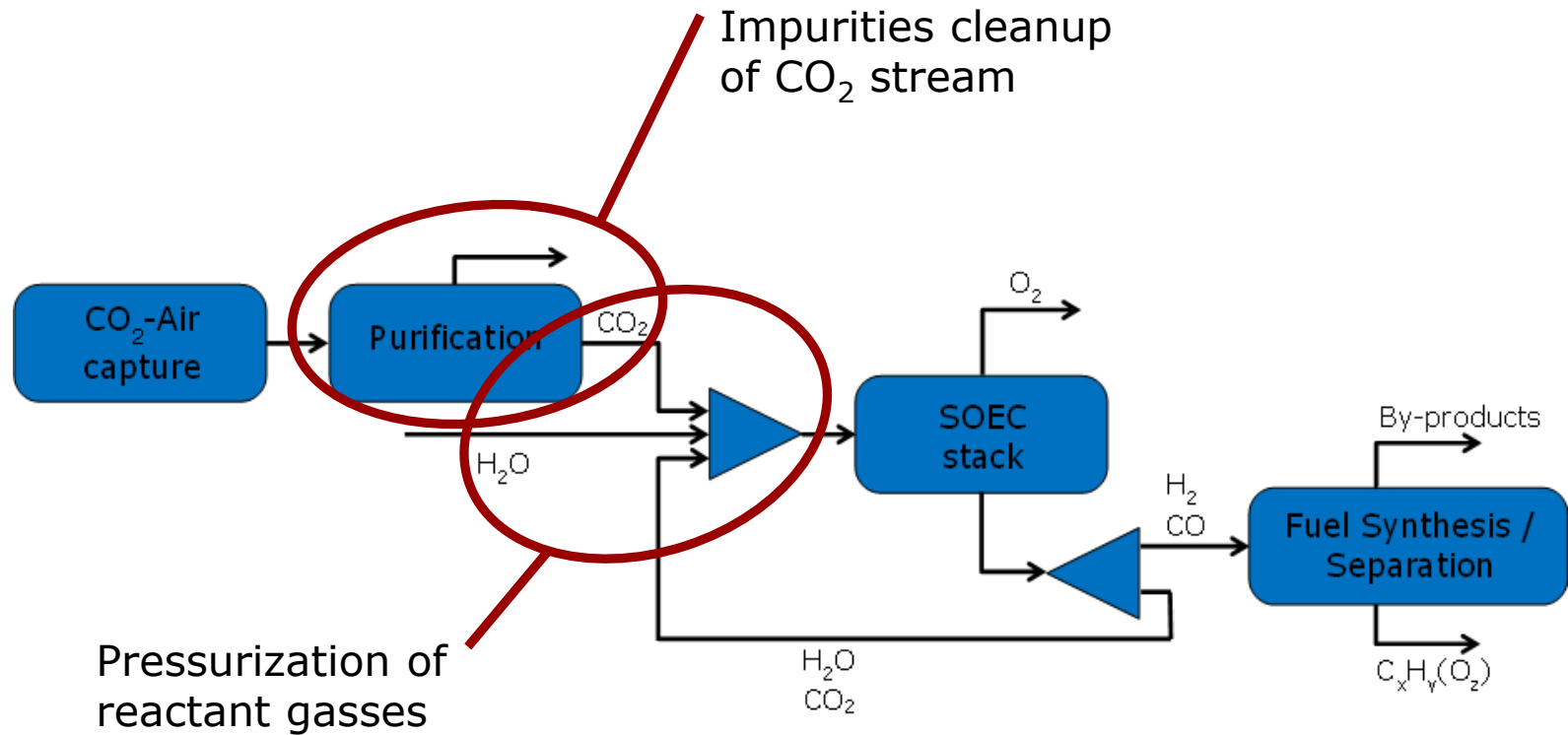
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Project vision

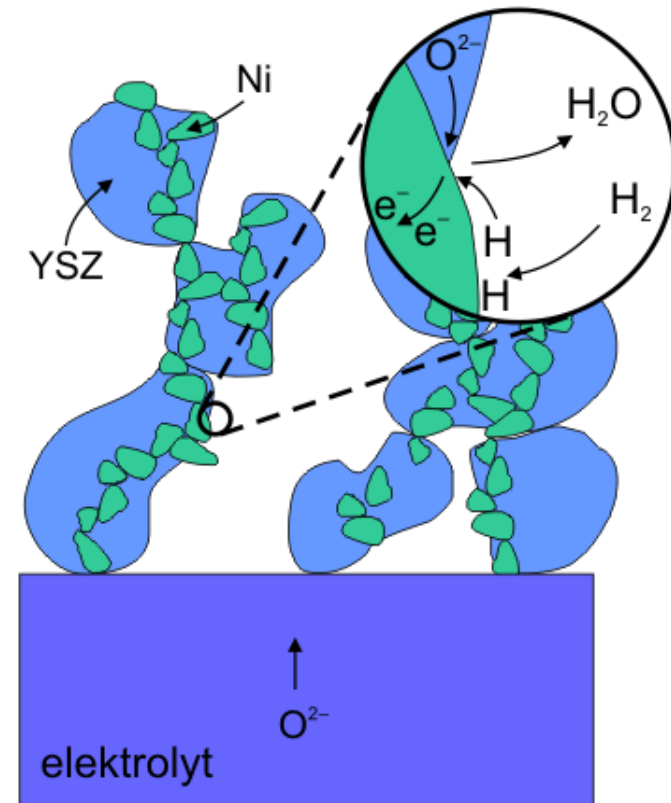
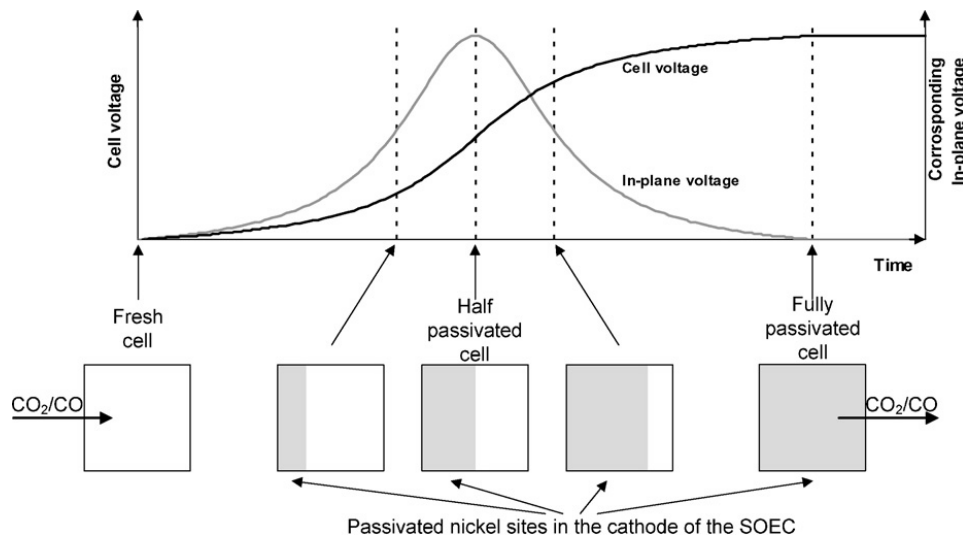


Project vision



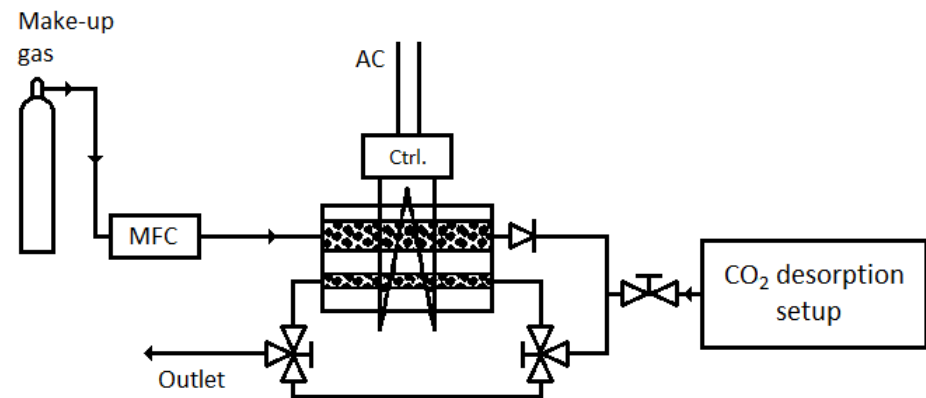
Impurities and SOEC operation

- Glassy Na, Si, Al, etc. Blocks catalytically active sites (TPB)
- Sulfurous compounds etc. block Ni surface sites
- Deposition damages structural integrity (carbon formation)
- Measurable below 5 ppb (H_2S)



Impurity collection experiments

- Solid state adsorption of trace impurities
- Crushed cathode material (Ni/YSZ)
- Operated at 1023 K
- Reducing conditions



Climeworks Ltd.:

- functionalized amine based
- temperature-vacuum swing
- pre-pilot prototype
- ~99% CO₂ (N₂, O₂, H₂O)

Lenfest Centre for Sustainable Energy:

- an-ion exchange resin based
- carbonate-bicarbonate humidity swing
- simple bench scale setup
- 0.5~5 % CO₂ (N₂, H₂O, H₂)

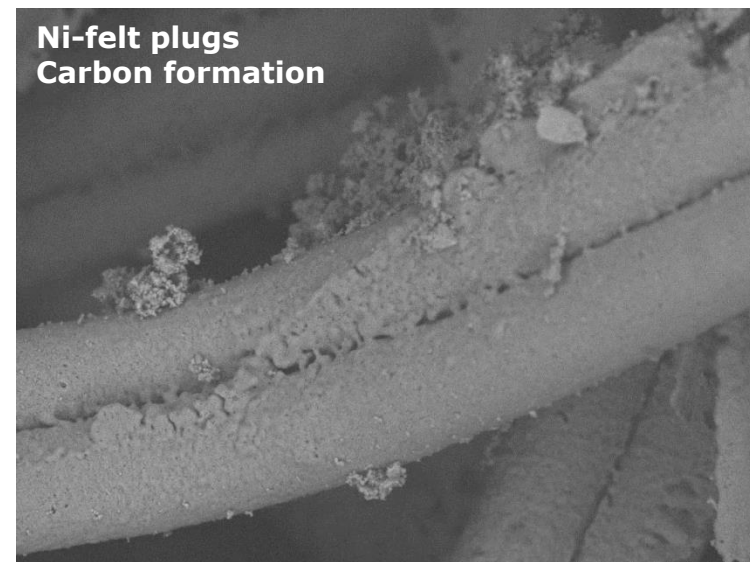
Correction: revised numbers in table

Elemental analysis of impurities

- Sorption on Ni/YSZ granulate (fuel electrode material)
- Operated at 1123 K
- Elemental analysis by XPS, EDS, SEM and Glow Discharge Mass Spectrometry (GDMS)
- Detection limit: $\sim 10 \pm 2$ ppb (in gas)

Element	Content in CO ₂ [ppm molar]	
	LCSE	Climeworks
B	-6.9 ± 9.7	-8.0 ± 17.3
Na	-13.6 ± 4.6	-10.1 ± 10.7
Mg	5.6 ± 8.2	0.0 ± 8.7
Al	-8.3 ± 13.3	0.5 ± 9.1
Si	4.1 ± 6.5	1.5 ± 9.5
P	-0.1 ± 0.1	-0.1 ± 0.1
S	1.2 ± 0.2	-0.2 ± 0.1
Cl	3.4 ± 1.3	3.6 ± 4.9
Co	1.6 ± 6.9	3.8 ± 11

GDMS elemental analysis



Ni-felt-U-0004

2013-10-17

N

D4,2 x1,2k 50 um

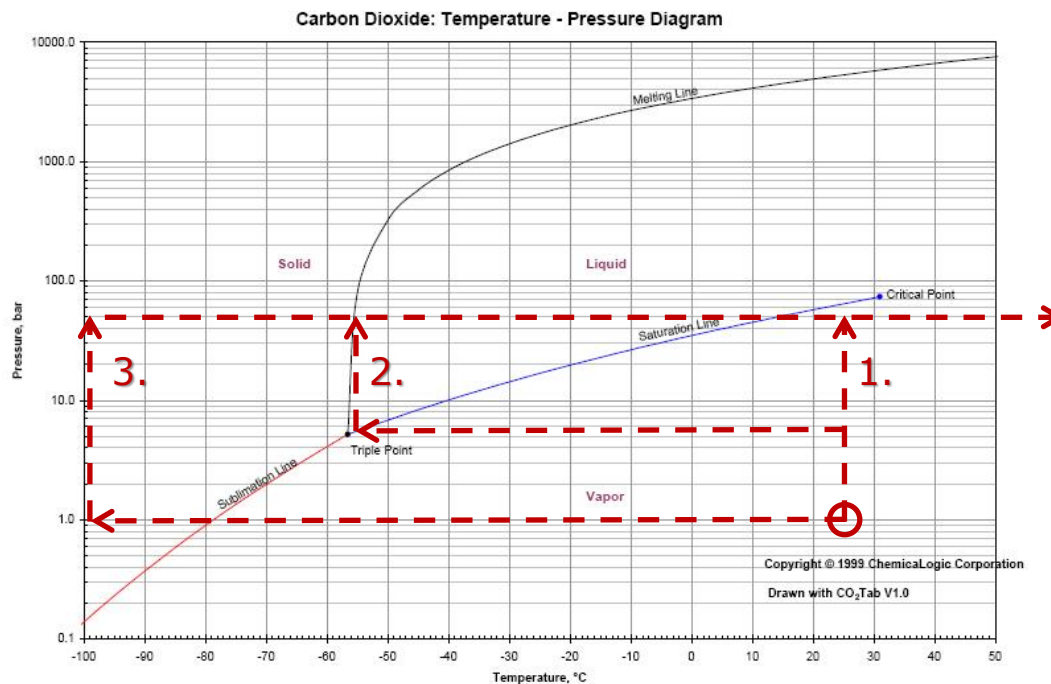
Elemental analysis: Glow Discharge Mass Spectrometry

- Various trace elements present in low concentrations
- Many are expected to be harmful for high purity applications (÷ carbon)
- Expected impurity sources:
 - Machine parts
 - Sorbent and filter material contaminants
 - Adhesives/oils
 - Captured from air (difference in location?)
- Most of these are preventable (minimize) in real systems
- Cheap and reliable filtering strategies available and tested
 - Ni/YSZ filter required for S-content <8 ton/1000 ton CO₂
 - Easily regenerated by redox-cycling

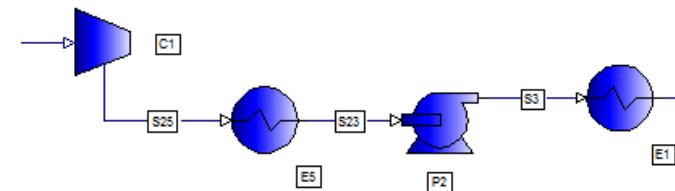
Compression cases

1. Base case: Simple compressor
2. Cryo: Cryogenic compression (5.15 atm, 205 K)
3. Solid Cryo: Cryogenic via solid CO₂ (1 atm, 187 K)

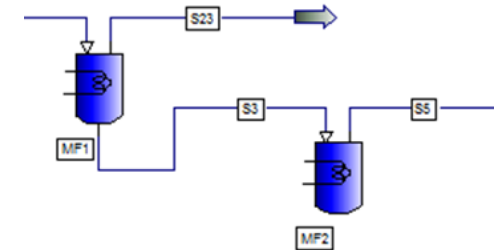
Inlet: ambient, outlet: 50atm, 533 K



2.

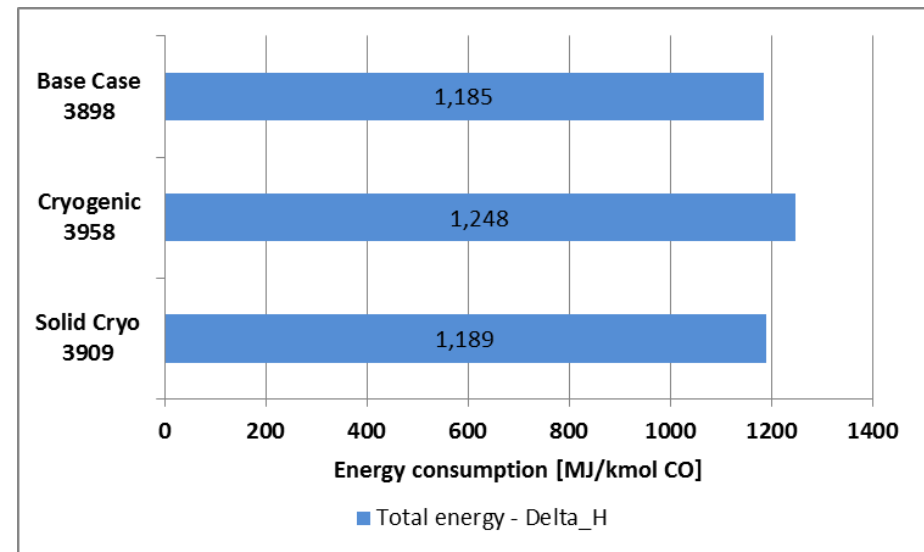
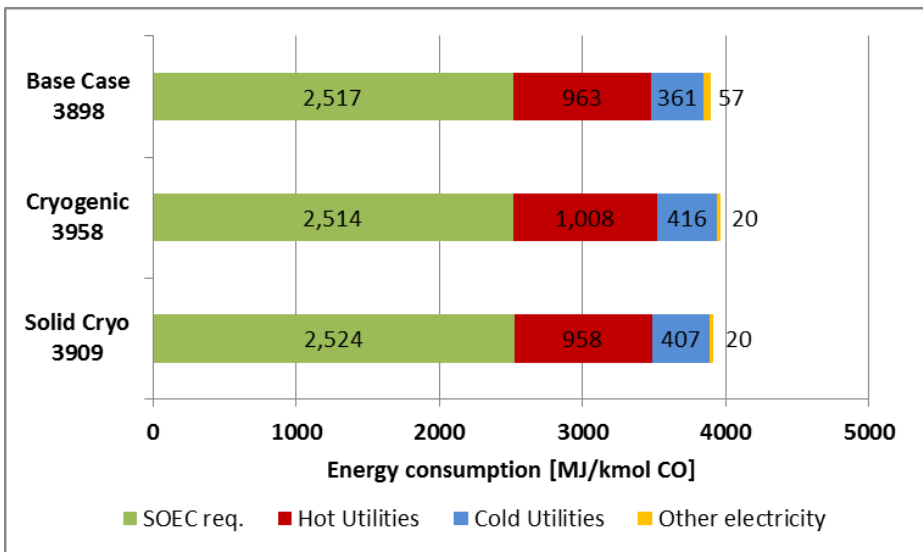


3.



Energy balance

- Energy consumption based on production of CO
 - 1 mol CO
 - ~6 mol H₂
 - 1 mol CH₄
 - H₂ : (CO+CO₂) = 3 : 1
- Heat integration pinch analysis:



Conclusion and future work

- Impurities pose a minor problem for SOEC operation and will probably require filtering
- Careful selection of materials will solve some of the problem
- Cheap, efficient filtering strategies exist to take care of the rest

- Alternatives to simple compression of CO₂ exists
- Further heat integration analysis, sizing and costing is needed to evaluate these

- Sorbent based compression is being looked into
- Further system analysis is planned
 - Including matching to various fuel synthesis technologies

Acknowledgements

- Eurostars E! CAPFUEL - CO2 capture from air and conversion into hydrocarbon fuels



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 - Allen Wright



- DTU Energy Conversion:
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 - Dr. Sune Ebbesen
 - Anders Petersen

